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Review Article

Strategies to increase children's vegetable intake in home and community settings: a systematic review of literature

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Abstract

A systematic review was undertaken to identify intervention characteristics associated with increasing consumption of vegetables in children (2–12 years). PubMed, PsychINFO and CABabstracts were used to identify studies published between 2004–2014 that had measures of vegetable consumption, a minimum of 3-month follow-up and were conducted in home and community settings (outside of schools). Twenty-two studies were included in the review. Details of the study design, population, setting, intervention characteristics, target behaviour, behaviour change techniques used and vegetable intake were extracted. Study quality and intensity were scored. Overall, 12/22 studies were effective short-term, and 6/10 were effective long-term (6 + months); mean short-term change in vegetable intake was 29%, equating to an increase of a quarter to a half of a serving of vegetables. Intervention effectiveness was associated with number of settings targeted and frequency of contact but not length of intervention. Planning for social support, vegetable exposure and provision of staff training were commonly used behaviour change techniques in effective interventions. This review has identified strategies that may optimise effectiveness of future home-based and community-based interventions aiming to increase vegetable intake in young children.

Keywords: vegetables, vegetable intake, child, home, community, intervention.

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Introduction

Vegetables are an important source of dietary fibre, provide a range of nutrients and have a low energy density. Dietary guidelines recommend we consume plenty of vegetables, including a range of different types and colours (U.S. Department of Agriculture and U.S. Department of Health and Human Services 2010; National Health and Medical Research Council 2013). Vegetable intake is protective against chronic diseases including heart disease and some cancers (Boeing *et al.* 2012) and may help to reduce the risk of obesity (National Health and Medical Research Council 2013). Despite the compelling public health benefits, dietary surveys in large population groups report that children do not meet vegetable intake recommendations (Yngve *et al.* 2005; Magarey *et al.* 2006; Kimmons *et al.* 2009; Australian Bureau of Statistics 2014). Critically, the prevalence of inadequate vegetable consumption increases as children transition from their early years through to adolescence, coinciding with higher intake recommendations. In Australia, the 2011–2013 Australian Health Survey reported that 49% of children aged 2–3 years met the recommended usual intake of vegetables, compared with less than 10% of children aged 4 to 18 years (Australian Bureau of Statistics 2014). This pattern of low vegetable intake in children is particularly concerning given that establishing appropriate healthy eating behaviours early in childhood influences the formation of eating patterns later in life (Maynard *et al.* 2006).

Numerous studies have aimed to increase children's vegetable consumption; however, systematic reviews of these report limited effectiveness (Knai *et al.* 2006; Evans *et al.* 2012), particularly in young (Wolfenden *et al.* 2012) and overweight children (Bourke *et al.* 2014). A comprehensive review of primary school-based initiatives that promoted fruit and vegetable intake reported a small increase in children's self-reported intake (+0.3 to +0.99 servings); however, the

majority of this modest increase was attributed to fruit not vegetables (Knai *et al.* 2006). A more recent meta-analysis that focussed on school-based interventions in children aged 5–12 years reported a small net effect for self-reported fruit intake (+0.24 servings) but virtually no increase in vegetable consumption (+0.07 servings) (Evans *et al.* 2012). Given children's low intake of vegetables and the differences in the context for vegetable consumption compared with fruit (Australian Bureau of Statistics 2014), it is important that interventions specifically targeting vegetable consumption are better understood.

In addition to specifically measuring the impact of interventions on vegetable intake, it is important to identify the strategies associated with changing the eating habits in children and describe 'how' initiatives were undertaken. Previous reviews of interventions to increase vegetable intake in children have focussed on the magnitude of change and overall effectiveness, with little detail on the components of the intervention per se. Knai *et al* qualitatively observed that increased exposure to fruit and vegetables was the key intervention component common to effective studies (Knai *et al.* 2006); however, a systematic critique of intervention components was not conducted. Recently, Diep *et al.* (2014) conducted a meta-analysis to determine whether interventions based on a theoretical framework were more effective at increasing children's fruit and vegetable intakes, than interventions with no theoretical underpinning (Diep *et al.* 2014). They reported that basing an intervention on behavioural theory has a small to moderate enhancement on effectiveness, and after controlling for study quality, this effect was greatest for vegetable consumption (compared with fruit or combined fruit and vegetables) (Diep *et al.* 2014). Further exploration of how interventions are undertaken (i.e. the strategies associated with successful interventions) and identification of behaviour change techniques (BCT) that may be associated with increased vegetable intake in children is warranted.

Therefore, a key aim of the current review was to identify the intervention characteristics and BCTs associated with increasing children's vegetable consumption. The review was focused upon studies targeting young children (2–12 years) to address the decline in intake that has been observed throughout childhood, to target an age range where children are more malleable and when establishing food acceptance may influence future eating habits (Birch & Ventura 2009; Anzman *et al.* 2010). The wider age group allowed us to include all children of pre-school and primary school age (2–12 years in Australia) but excluded adolescents who have greater autonomy over their eating habits and a higher vegetable intake recommendation. Given our target age range and the scope of previous reviews (Knai *et al.* 2006; Evans *et al.* 2012), this review focused on interventions delivered in home or community settings (community centres, childcare centres, kindergartens, afterschool care settings and internet based programs); i.e. outside of the school setting.

Methods

This systematic review was carried out and reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) 2009 Checklist (Supplementary Appendix).

Key messages

- This review identified 22 prospective studies that reported vegetable intakes among children aged 2 −12 years in the home and community settings.
- Overall, 12/22 studies were effective short-term (3 months follow-up), and 6/10 were effective longer term (6 months or more).
- Mean short-term change in vegetable intake was ~30%, which based on current intake equates to an average quarter to a half a serve increase.
- The design and behavioural change techniques associated with effectiveness were identified, including planning for social support, vegetable exposure and provision of staff training.

Search method for identification and screening of studies

PubMed, PsychINFO and CABabstracts were searched for scientific literature published between 2004 and June 2014 to identify intervention studies that targeted vegetable consumption in children aged 2–12 years. Only peer reviewed published scientific papers were included in the search; unpublished work or 'grey' literature was excluded. The initial search included the following MeSH (medical subject headings) terms and combinations thereof under the three headings: (1) interventions: research design, controlled clinical trial, randomised controlled trials, random allocation, double-blind method, single-blind method, placebos, intervention studies, evaluation studies, comparative study, follow-up studies, prospective studies, cross-over studies, clinical trial, latin square, time series, study, studies, trial, random, RCT, matched communities, matched schools, matched populations, control, comparison group, control group, comparative study, matched pairs, outcome study, outcome studies, quasi experimental, pseudo experimental, nonrandomi, non randomi, pseudo randomi, quasi randomi, prospective, volunteer, experimental, intervention, model, models, evaluation, and cross-over; (2) vegetable intake: vegetables, vegetable, vege; (3) children (2–12 years): child, adolescent, pre-school, schoolchildren, school children, pediatr, boys, girls, youth, young people, infant, and toddler.

After removal of duplicate records, four investigators (GH, DB, JB & HL) independently analysed the title and abstracts of each paper retrieved in the initial search to identify eligible studies. Studies not meeting the inclusion criteria (below) were excluded. The remaining papers were obtained, and a final full-text analysis to identify eligible studies was performed. The screening process and article selection is summarised in (Fig. 1).

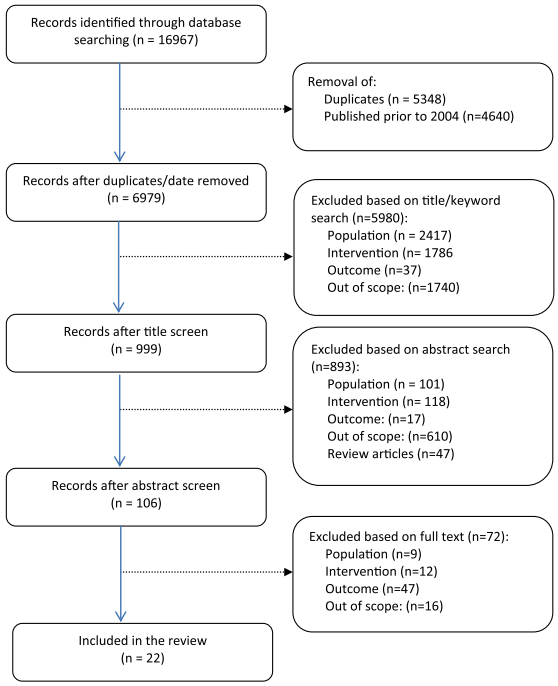

Fig. 1. Summary of the screening and article selection process.

Inclusion criteria

Studies were eligible for inclusion if they met all of the following criteria: prospective studies evaluating the effectiveness of an intervention, with or without comparison groups; intervention aimed at improving vegetable consumption, either alone or in combination with other healthy eating and lifestyle messages; had a quantitative measure of vegetable consumption separate to other food groups (such as fruit), reported at an individual or group level in either grams, servings, frequency of consumption (times per day), provision (number of vegetables available or served) or purchase habits (shopping receipts); the measure of vegetable consumption was reported as an estimate of 'usual' vegetable intake (not intake of a test dish/meal); the intervention was delivered in the home or a community setting including community centres, childcare, kindergarten and afterschool-care settings or as part of government initiatives; the intervention targeted children aged 2–12 years or had a mean population age of ≥2 years and ≤12 years; the outcome was reported at three months post intervention or more (to assess sustained behaviour change and habit formation); and was published in English between 2004 and 2014 in a peer reviewed journal.

Exclusion criteria

Studies targeting specific subgroups of the population such as clinical populations, case studies and children

with specific medical conditions were excluded to make the findings relevant to the general population. Similarly, studies reporting intake measures of test vegetable dishes/meals or single vegetables were also excluded as these were not estimates of 'usual' consumption and therefore not reflective of the child's usual vegetable intake. Interventions delivered in schools (i.e. with or without a home or community component) were excluded as these have been the focus of another recent review (Evans *et al*. 2012).

Data extraction and synthesis

Details were extracted for the study design, population, setting, intervention characteristics, target behaviour, behaviour change techniques used and vegetable intake. Two reviewers (DLB and JB) independently extracted the data from papers including study design, intervention duration, setting (i.e. home, community, pre-school/childcare, afterschool programs) and target (i.e. intervention recipient; children, carers, parents), population (including sample size, age and gender of children), intervention characteristics, contact with intervention and behavioural target of the intervention (i.e. improving vegetable intake only, fruit and vegetables, a healthy diet or diet and lifestyle), data time points and vegetable intake pre-intervention and post-intervention. Short-term (>3 months) and longer term (>6 months; data available for 10 of 22 studies) effectiveness were defined as a significant ($P < 0.05$) increase in vegetable consumption as reported by the author. Refer to the Supplementary Appendix for the full comprehensive data extraction table. Each study was extracted by a single author. A second author reviewed 20% of studies to ensure accuracy of data extraction and coding. Any inconsistencies were resolved by discussion with a third author (GH).

A number of study design and intervention components were coded using published protocols as detailed in the succeeding sections. An assessment of intervention intensity enabled a comparison of results between all studies despite their varied study design and settings. The intensity rating was based on a Cochrane review of community wide interventions for increasing physical activity (Baker *et al.* 2011; Francis *et al*. 2011). Four aspects of the intervention were coded, each scored on a 5-point scale (1 = low intensity to 5 = high intensity) with a low, medium and high ranking on each component as follows:

- Duration of intervention: <6 weeks = 1, 12 weeks to < 6 months = 3 and >12 months = 5.
- Contact with intervention: yearly = 1, monthly = 3 and daily = 5.
- Type or level of contact: physical, policy or legislative or no face-to-face = 1, group level = 3 and individual contact = 5.
- Reach (number of settings targeted): 1 setting = 1, 2 settings = 3 and ≥3 settings = 5.

An overall intensity score out of 20 was calculated. Based on the range of scores in this review and our previous use of the tool (Hendrie *et al.* 2012), scores ≤10 were considered lower intensity, 11–12 were medium intensity and ≥13 considered higher intensity.

Study quality was scored using the standard published protocol for the Effective Public Health Practice Project quality assessment tool (Thomas 2003; Thomas *et al*. 2004a). Eight components were scored (selection bias, study design, confounders, blinding, data collection methods, withdrawals and drop outs, intervention integrity and analyses) from which an overall quality rating was calculated (strong/moderate/weak) (Thomas 2003; Thomas *et al*. 2004a).

The Behaviour Change Techniques used in the interventions were double coded by a health psychology researcher (HL) using standardised definitions outlined in the CALO-RE taxonomy of BCTs (Abraham & Michie 2008; Michie *et al*. 2011). The taxonomy defines 40 BCTs with standard definitions provided in a coding manual. Six additional categories were added to the original taxonomy to account for unique, recurring techniques used in the interventions in this review; tasting and exposure techniques, provision of resources, staff training, community/participant engagement, economic incentives, increasing availability and accessibility within the local environment through, for example, community gardens.

A meta-analysis of the magnitude of change in vegetable intake was not possible because the methodologies used to measure intake of vegetables were

heterogeneous between studies (e.g. number of serves/day, grams consumed) and was only available for 17 out of the 22 studies. However to have some indication of intervention impact, the change in vegetable intake was calculated as the percentage increase/decrease in the unit reported, regardless of significance levels.

Results

Describing the studies overall

The 22 papers included in this review were published between 2004 and 2014 and are summarised in Table 1. Complete data extraction is available in the Supplementary Table. The interventions ranged in length from a single nutrition education newsletter mail out to a 3 year community garden-based intervention. Seven interventions were home-based, and the remainder were either set in pre-school or childcare ($n = 6$), after-school programs ($n = 4$) or community programs ($n = 5$). They targeted vegetable intake only ($n = 4$), intake of fruit and vegetables ($n = 6$), vegetables as a part of a healthy diet ($n = 6$) and as part of a healthy lifestyle ($n = 6$). Overall, 12 of 22 studies (54%) were considered effective in increasing children's vegetable intake in the short-term, and six of ten (60%) were considered effective longer term. Most studies ($n = 15$) had a medium intensity rating, with five rated low and two rated high intensity. Fourteen studies had a weak quality rating, and seven were rated as moderate quality, with only one paper rated as strong quality (See Table 1 & Supplementary Table for full details extracted from each study).

Characterising interventions by effectiveness

Short-term and longer term effectiveness

Table 2 summarises the intervention characteristics for effective and ineffective studies separately for short-term and longer term outcome measures. The majority (8 out of 12) of interventions that targeted children's vegetable intake in the context of either a healthy diet or healthy lifestyle were effective in the short-term, whereas one out of four interventions that targeted vegetables alone were effective in the short-term. None of the interventions that focused solely on vegetable intake had an outcome measure at 6 months or more. Of the six studies that were effective longer term, half focused on vegetables within the context of a healthy diet, the others on increasing fruit and vegetables ($n = 2$) or as part healthy lifestyle generally ($n = 1$) (Table 2).

Intervention setting, duration, intensity, quality and contact with participants

Table 3 summarises the setting, duration, intensity and quality of effective and ineffective studies, by short and longer term follow-up. There were seven studies delivered in the home, six in pre-schools, four in after school programs and five in the community. While the home was a common setting, it was the least likely to be effective in the short-term ($n = 2/7$). There were four after-school programs, three of which were effective in the short-term. Longer term, interventions within the pre-school setting were most likely to be effective. The duration of the intervention did appear to be associated with effectiveness. Effective interventions were more likely to be rated as medium to high intensity overall, with only one out of five low intensity intervention considered to be effective. There were two high-intensity interventions – both effective in the short and longer terms. Only one study was rated as strong quality and this was considered effective in the short-term; however, it did not include a follow-up measure at 6 months or more. Effective interventions scored higher in terms of their contact with participants (3.75 vs. 2.7 out of 5) and their reach (2 vs. 1.2 out of 5) (See Table 4).

Behaviour change techniques (BCTs)

Table 5 summarises the BCTs used by effective and ineffective studies and by short and longer term follow-up. Overall, the most commonly used behaviour change techniques were the provision of resources (82%), information on the consequences of consuming and not consuming vegetables (73%), modelling or demonstrating the behaviour (64%), prompt practice (59%) and providing instruction on how to perform the behaviour (54%). Half of the interventions included planning for social support or change as a tool to increase vegetable intake, and this technique was associated with effective behaviour change in both the short-term (8/11 studies) and longer term (6/7 studies).

Table 1. Description of studies included in the review that assess the impact of an intervention of vegetable intake in the home and community settings

Reference	Study design; duration; setting; target	Population: sample size (*N*); Age M ± SD (range); % male	Intervention description; contact with intervention	Data time points; Comp; CG	How was vege intake measured?	Intake pre-intervention	Intake post-intervention	Intake at Follow-up	Change in vege consumption
Annesi *et al.* 2009	Cohort; 12 weeks; ASP; children	43 9 ± 1.3 years (7–12 years) 49%	Youth fit for life program included PA, behavioural skills training, health and nutrition education. Contact: 3 × 45 min sessions/week (20 min Cardio PA/session), 2 × 20 min/week strength training, 20 min × 1/week behavioural skills, health and nutrition info 5–7 min/session)	TP: baseline, post-I Comp: not stated CG: none	FFQ (2 items): *frequency*/ week	9.93 (SD ± 5.15)	12.47 (SD ± 7.21)	—	$t42 = 2.12$, $P = 0.02$, $d = .49$
Bayer *et al.* 2009	Cluster RCT; 2 years; Kindy; Children & teachers & parents	64 kindy's, 1605 children 6 ± 0.4 years (5–6 years) 52–64%	'TigerKids' behavioural intervention targeted at: PA games at kindergarten, F&V consumption and habit formation of ≥2 FV portions/day & drinking water in kindy. Information materials & day-to-day activities to teachers, phone hotline for teacher support, information for parents, internet platform with info for teachers & families & shared FV plates offered. Contact: ~5 h/week	TP: baseline, 3–9 m, 12–20 m Comp: not stated CG: usual care	FFQ: portions/ day converted to % high V consumer ≥2portions	—	# of high vege consumers' sample 1: I: 323, 38.6% (35.3–42.0) C: 155, 33.9% (29.6–38.5) $P = 0.0960$ sample 2: I: 366, 42.7% (39.4 to 46.1) C: 151, 33.6% (29.2 to 38.1), $P = 0.0013$	— 0	Intervention effects Sample 1: OR 1.26 (0.98–1.61) Sample 2: OR 1.48 (1.08–2.03)
Castro *et al.*, 2013	Cohort; 3 years; community; families	120 (60 families) 6 ± 3.4 years (2–15 years) 49%	Growing healthy kids program: weekly sessions in community garden (staff assisted with garden preparation, planting etc), 7-week cooking & nutrition workshop (information & resources for healthy food choices), social events for families and garden newsletter. Contact: Weekly	TP: Baseline, 1, 2 & 3 years comp: family gardening participation 45% weekly, 45% 2–3×/month, 7%1/month, 3% no attendance data. CG: none	Survey (parent report): V variety available at home; usual servings consumeday/ weekday	Availability: 3.5 ± 2.06 usual intake: 2.1 ± 0.96	Availability: 7.8 ± 1.80 usual intake: 2.8 ± 1.28	—	Availability: 4.3 ± 1.82 (123% increase, $t = 16.37$, df = 47, $P < 0.001$) Usual intake: 33% increase ($t = 3.17$, $df = 45$, $P < 0.001$)

(*Continues*)

Table I. Continued

Reference	Study design; duration; setting; target	Population: sample size (*N*); Age M ± SD (range); % male	Intervention description; contact with intervention	Data time points; Comp; CG	How was vege intake measured?	Intake pre-intervention	Intake post-intervention	Intake at Follow-up	Change in vege consumption
Corsini *et al.* 2011	RCT; 2 weeks; home; parents, children	185 children & caregiver (4–6 years) 59%	3 groups: EO, exposure + reward (E + R) & control. EO group required parent to present & ask child to taste small piece of target vege daily for 2 weeks. E + R group same as EO procedure + 14-day sticker reward chart for tasting the vege. Contact: short daily activity	TP: Baseline, post-I (2 & 4 weeks, & 3 months) Comp: 94% returned exposure diary. 86% offered target V on ≥ 10 occasions. 56% children achieved 10 taste exposures. CG: normal feeding behaviour	Target V: g consumed usual intake: FFQ *f*/day Variety: number V/ week	—	—	—	Target V intake: All increased from baseline ($X^2(1) = 22.98$, $P < 0.001$) E + R increased post-I to 3 months (change 6.47, SE 2.26, $P = 0.013$) & 4 weeks to 4 months (change 7.23, SE 1.49, $P < 0.001$) C: increased Post-I to 3 months (change 3.51, SE1.22, $P = 0.012$) usual V intake: variety increased with time ($F(2,126) = 30.23$, $P < 0.001$) frequency, E + R increased from baseline to 4 weeks (change 0.32, SE0.12, $P < 0.5$)
Davis, 2011	Pilot cluster RCT; 12 weeks; ASP; childre and, parents	104 9.8 ± 0.7 years 52%	Cooking /nutrition education, gardening lessons & market garden visits + 60 min parent nutrition & gardening class Contact: 90 min/week	TP: Baseline, 1-week post-I Comp: parent component – 25% participation CG: abbreviated delayed intervention after post-testing of IG.	FFQ (41 items): servings/day (previous day)	I:1.6 ± 1.0 C:1.9 ± 1.3	I:1.6 ± 1.0 C:1.3 ± 1.0	-	I v C, $P = 0.11$
De Bock, 2011	Cluster RCT; 6 months; pre-school; children; parents	377 (18 pre-schools) 4.26 ± 0.78 years (3–6 years) 53.2%	Nutrition intervention: education on different foods, preparing, cooking, shared meals, parent education (modelling & child nutrition needs), interactive play, active parent participation & peer interaction. FV & water offered every week to increase exposure. Contact: 2 hours/week × 15 nutrition sessions (10 children only, 5 parents only or parent & child)	TP: baseline, 6 & 12 months Comp: not stated CG: waiting list control arm (received the intervention 6 months later).	FFQ: portions/ day	34.6% achieved recommended daily vege intakes	—	—	Intervention effect higher post intervention unadjusted: +0.22 points $P < =0.01$ Adjusted: +0.15 points, $P = 0.027$ **a change of 1 point = ~ 1 portion

(*Continues*)

Table 1. Continued

Reference	Study design; duration; setting; target	Population: sample size (*N*); Age M ± SD (range); % male	Intervention description; contact with intervention	Data time points; Comp; CG	How was vege intake measured?	Intake pre-intervention	Intake post-intervention	Intake at Follow-up	Change in vege consumption
Engels *et al.* 2005	Pilot cohort; 12 weeks; ASP; children, parents	56 children (25 parents) 11.1 ± 1.3 years 32%	Program employed social, cognitive, & behavioural strategies. Content included: dance, sport, fitness & nutrition activities, targeted handouts & poster-board display, & motivational talk by public figure. Participants required to record daily FV intake & step counts. Contact: 60-75 min sessions 4 days/week	TP: Pre & post-I Comp: not stated CG: no Control	FFQ: *f/day (converted to 0–10 score)*	Green salad (+/− other V): 3.42 ± 1.97; fries/fried potato: 3.60 ± 1.54; boiled/ mashed potato: 2.79 ± 1.66 V servings (−salad V/ potato): 3.96 ± 1.69	Green salad (+/-other V): 4.58 ± 2.80; fries/fried potato: 3.92 ± 2.79; boiled/ mashed potato: 3.70 ± 2.33; V servings (−salad V/ potato): 4.36 ± 2.20	—	Green salad (+/−other V): +1.16, $P = 0.003$ Fries/fried potato: +0.32, $P = 0.278$ Boiled/ mashed potato: +0.91, $P = 0.005$ V servings (−salad V/ potato): +0.4, $P = 0.276$
Freedman & Nickell, 2010	Cohort; 3 weeks; Local library; Children (+1 session for parent & child)	49 11.1 ± 0.03 years (9–14 years) 36%	'Snack Smart' workshops: nutrition education through videos, food prep, tastings, label-reading, games, creating recipes, handouts, role modelling, goal setting, barriers, home activities, social support networks. Reinforcements used + recipe book & draw prize post-I. Contact: 6 h total; 3 × 90 min/week after-school nutrition workshops, 2 × 45 min weekend workshops	TP: Baseline, post-I, 3–4 months Comp: Not stated CG: children acted as own control	FFQ: *f/d* (converted to 0–3 score)	—	—	follow-up - pretest −1.17, $P = 0.24$	posttest – pretest: −2.12, $P = 0.03$
Gholami *et al.*, 2015	RCT; education leaflet mailed out; Home; Mothers	155 mothers with daughters aged 6–11 year mothers: 34.13 ± 5.87 years (25–50 year) NA	Theory-guided instructional leaflet provided to mothers after baseline; included info on consequences of behaviour, WHO healthy eating recommendations, instructions on how to perform behaviour, dietary action planning and coping planning exercises. Contact: Education leaflet mailed out	TP: Baseline, 2 weeks, 3 months Comp: Not stated CG: not stated	Survey: Usual portions/day	I: 2.42 (SD 1.44), C: 2.80 (SD 1.71), ($t = 1.54$, $d = -0.24$, $P = 0.12$)	2 weeks I: 3.09 (SD 1.86), C: 2.53 (SD 1.63), ($t = -2.07$, $d = 0.32$, $P = 0.04$)	3 month I: 3.05 (SD 1.48), C: 2.87 (SD 1.45), $t = -0.80$, $d = 0.12$, $P = 0.42$	Main effects: time effect $P = .03$, No treatment effect $P = .67$. Interaction between time and treatment existed $P = 0.02$ (I group higher at time 2, not time 3)

(*Continues*)

Table I. Continued

Reference	Study design; duration; setting; target	Population: sample size (*N*); Age M ± SD (range); % male	Intervention description; contact with intervention	Data time points; Comp; CG	How was vege intake measured?	Intake pre-intervention	Intake post-intervention	Intake at Follow-up	Change in vege consumption
Haire-Joshu *et al*., 2008	Group randomised nested cohort design; 7 months; home; family	1306 families with preschool aged child (2–5 years) —	High 5 for Kids: tailored newsletter based on pretest interview, home visits & materials for parent & child. Intervention strategies targeted knowledge, parental modelling, feeding practices, FV availability. Contact: 4 × 60 min home visits + newsletters	TP: baseline, 7 months Comp: Program delivered to 78% intervention families, 84% completed posttest CG: standard program	FFQ (27 items): Servings/day	I: 1.55 C: 1.46	I: −0.02 C: −0.04	—	Intervention effect, adjusted 0.06, $P = 0.10$
Horne *et al.*, 2011	Randomised cross over trial; 2 phases 30 days each; childcare; children	20 34 months (24–52 months) 40%	Modelling & rewards intervention: videos screened during intervention featuring animated characters modelling consumption of target food & being rewarded for eating them. Letters from characters read out to reinforce target food, previous days intake and rewards. Rewards given for eating varying amounts of target foods. Contact: not specified	TP: baseline 1, fruit intervention, baseline 2, christmas break, baseline 3, vege intervention, baseline 4, 6 months follow-up. Comp: not stated CG: no control	Observational record: % consumed	Baseline 1 snacktime: 24.6% lunchtime: 17.9% Baseline 3 snacktime: 28.8% lunchtime: 30%	Post-I (cf baseline 3 intake) snacktime: 85.5% lunchtime: 76.9%	6 months (cf baseline 1 intake) snacktime: 85.1% lunchtime: 84.8%	post-I snack time: +56.7 ($t(19) = 7.09$; $P < 0.001$; $d = 1.73$) lunchtime: + 46.9 ($t(19) = 5.98$; $P < 0.001$; $d = 1.42$) 6 month FU snack time: +60.5 ($t(13) = 8.09$; $P < 0.001$; $d = 2.59$) lunchtime: +66.9 ($t(13) = 8.12$; $P < 0.001$; $d = 2.68$)
Horton *et al*., 2013	RCT; 4 months; Home; Families	361 families with ≥ 1 child aged 7–13 years no info	Intervention topics included: family relations/communication/ parenting styles, stress & eating, healthy eating & FV, social support. Also included DVD	TP: Baseline, 4 months 6 months Comp: retention rates I: 88%, C:91% CG:	Survey (2Q) Cups/day, Variety in last month (44 items)	—	Adj mean of daily cups of vege consumed: I: 1.19 (SE 0.07),	—	I vs. C post-I: cups consumed, $P = 0.14$ variety, $P = 0.067$

(*Continues*)

Table 1. Continued

Reference	Study design; duration; setting; target	Population: sample size (*N*); Age M ± SD (range); % male	Intervention description; contact with intervention	Data time points; Comp; CG	How was vege intake measured?	Intake pre-intervention	Intake post-intervention	Intake at Follow-up	Change in vege consumption
			series, goal setting sheets, skill building activities, child-directed activities & family weekly tasks. Contact: 14 contacts: 11 × home visits, 3 × calls), total 16.5 h.	delayed treatment intervention			C: 1.05 (SE 0.07) Adj mean of monthly variety of vege: I: 12.0 (SE 0.44), C: 10.8 (SE 0.43)		
Latif *et al.*, 2011	Cluster RCT; 9 weeks; community group; children	473 12.8 ± 1.1 years (10–4 years) 100%	2 x I groups (dietary or PA based). Dietary I: 5 A Day Badge program - functional knowledge & skills, tastings, recipe booklet. PA I: Fit for Life (FFL) Badge program - sporting activities, 'drills' booklet. Internet component: BCTs - goal setting/ review/modelling and problem solving Contact: 9 × 55 min/week group sessions (30 min in-troop activities/25 min internet activities)	TP: Baseline, post-I, 6 months post-intervention Comp: not stated CG: —	FFQ: servings/ day	I: 0.35 (SD ± 0.32) C: —	I: 0.44 (SD ± 0.36) C —	6 months Post I I: 0.38 (SD ± 0.36) C —	Post I: +0.09 6 months post I: +0.03 (C group NA)
Martinez-Andrade *et al.*, 2014	Pilot cluster RCT; 6 weeks; primary care clinic; families	306(189 completed 3&6 months FU) 40.6 ± 10 months (2–5 years) 52.6%	Intervention group: obesity awareness & prevention workshops. Topics: portion size, healthy eating, label reading, meal planning, PA & sun exposure. Techniques included motivational interviewing, reflexive listening skills, goal setting/review, barriers, activities (games, cooking). Contact: 2 h/week (90 min workshop, 30 min shared food).	TP: Baseline, 3 months, 6 months Comp: 40% compliance to educational sessions. 35% families did not complete 3 months FU. CG: Usual care	FFQ: Servings/ week	I: 20.9 (SD ± 15.0) C:20.6 (SD ± 20.1)	3 month FU I: 20.0 (SD ± 17.1) C:15.1 (SD ± 13.9)	—	3 months FU I: -0.8 (SD ± 0.2) C: -5.5 (SD ± 0.2) adj I-C dif 6.3 (95%CI 1.8,10.8) 6 months FU I: −3.1 (SD ± 0.2) C: -5.0 (SD ± 0.2) adj I-C dif 2.7 (95% CI −1.3, 6.7)
Namenek Brouwer &	Pilot RCT; 4 months;	12 (4 childcare centres) 73%	'Watch Me Grow' garden based program: grow a crop/month,	TP: Baseline, post-I (5 months)		Total V: I: 0.8 +/−0.68, C: 0.8	Total V: I: 1.05 +/−00.67, C:	—	Total V: I: 0.25 +/−01.1, C: -0.18 +/−00.52 dark V: 0.07+/−00.13,

(*Continues*)

Table I. Continued

Reference	Study design; duration; setting; target	Population: sample size (*N*); Age M ± SD (range); % male	Intervention description; contact with intervention	Data time points; Comp; CG	How was vege intake measured?	Intake pre-intervention	Intake post-intervention	Intake at Follow-up	Change in vege consumption
Benjamin Neelon 2013	Childcare; Children	aged 3–5 years —	weekly class activities (reading, tasting, garden, classroom). Program included a gardener to assist & health educator for menu review. Contact: 4 activities/month (~1/week). Duration not stated.	Comp: not stated CG: delayed intervention	Observation record: servings/2 days	+/−00.38 dark V: I: 0.00+/−00.00, C: 0.01 +/−00.02 white potatoes: I:0.17 +/−00.23, C: 0.22+/−00.39	0.63+/−00.28 dark V: I: 0.07 +/−00.13, C: 0.02+/−00.01 white potatoes: I: 0.33+/−00.34, C: 0.00 +/−00.00		C: 0.01+/−00.05 white potatoes: 0.16+/−00.54, C: 0.22+/−00.39
Schwinn *et al.* 2014	Cohort; 3 weeks; Internet; Mother daughter dyads	67 mother daughter dyads 11.85 ± 0.88 years (10–12 years) NA	3 session web delivered program to develop & maintain healthy relationships, bodies & minds. Topics: communication, family meals, knowledge of drugs, setting rules, food shopping skills, preparing healthy dinners, coping skills. Contact: 3 × 25 min sessions	TP: Baseline, post-test, 5 months FU Comp: 35/36 in intervention completed all sessions CG: no intervention materials	FFQ (21 items): *f*/week	2.28+/−00.9	1 week postI:2.38+/−00.81	5 months postI 2.41+/−00.99 NS	NS
Slusser *et al.* 2013	Evaluation pre/post test; 1 School year; After-school program; staff	121 from 8 ASP sites (I:4, Ct:4) 6–11 years 43%	Catch Kids Club: 32-lesson ASP teaching students nutrition & skills to make healthy dietary & PA choices. Intervention sites received staff training in nutrition, child development & PA routines, curriculum resources, mentoring & assistance visits, nutrition education manual, activity box, & snack prep activities. Contact: -	TP: Baseline (Sep), follow-up at the end of school yr (June). Comp: Not stated CG: No training or support provided	Survey: *f* (previous day)	I: 0.37 (SD 0.117) C: 0.36 (SD 0.092)	I: 0.37 (SD 0.284) C: 0.46 (SD 0.140)	—	Change score I: 0.00, C: +0.10, $P = 0.084$
Somerville *et al.* 2012	Evaluation with pre/post test; 13 weeks; Community; Children	40 9 y (6–12 years)-	Weekly activities included FV snack preparation, blind tasting, apple stamping, produce Pictionary, & FV bingo. Children encouraged to prepare & consume FV snacks during session & at home. Contact: 1 h/week	TP: Baseline, post-Is Comp: Not stated CG: No Control	Observation: Servings eaten at snacktime (FV combined) Survey (7 item): usual Servings/day	Usual servings/day 2.17 ± 1.82	Usual servings/day 3.07 ± 1.87	—	0.9, $P < 0.05$

(*Continues*)

Table 1. Continued

Reference	Study design; duration; setting; target	Population: sample size (*N*); Age M ± SD (range); % male	Intervention description; contact with intervention	Data time points; Comp; CG	How was vege intake measured?	Intake pre-intervention	Intake post-intervention	Intake at Follow-up	Change in vege consumption
Tabak *et al.* 2012	Pilot RCT; 4 months; Phone + print materials; Parents	43 families 3.6 ± 0.8 years (2–5 years) 16%	Intervention: 4 tailored monthly newsletters & 2 motivational phone calls. Calls addressed V/food issues from baseline surveys, areas for improvement, encouraged parents to describe successes, use problem solving to overcome barriers, receive support & encouragement. Newsletters addressed: V availability, picky eating, family meals, role modelling, individual feedback, goal setting, recipes, tips, resources and goal tracking. Contact: 4 monthly newsletters & 2 calls	TP: baseline, post-I (~5 months) Comp: not stated CG: 4 children's books (non-health/nutrition related) (1/month)	FFQ: servings/ day	I: 0.8 (SD 0.4) C: 0.6 (SD 0.4)	—	—	change in mean ($P = 0.61$ adj) I: +0.1 (SD 0.3) C: +0.0 (SD 0.5)
Witt & Dunn 2012	RCT; 6 weeks; pre-school; children	263 from 17 childcare centres 4–5 years 53%	Colour me Healthy: designed for 4–5 years old pre-schoolers & delivered by pre-school teachers, provides interactive learning & teacher toolkit (lesson guides, picture cards, posters, music CD, hand stamps, parent newsletters etc). Activities encourage discussion about FV, tasting experiences. Contact: 3 sessions/ week, 15-30 min each	TP: baseline, post-I, 3 months post-I Comp: attendance 14.2 ± 4.0/18 lessons; completed take-home activities 3.4 ± 2.4/6 CG: no treatment	Weighed record: % of 1 Cup serve consumed	I: 37.9% C: 35.6%	I: 62.1% C: 33.2%	I: 71.0% C: 34.0%	Main effect for time (F [2,240] = 21.67, $P < 0.01$) Interaction effect (F [2,240] = 27.65, $P < 0.01$) I: higher intake post-I (F [1,120] = 24.14, $P = < 0.001$; $d = 0.90$) & FU (F [1,120] = 43.41, $P = < 0.001$; $d = 1.20$)

(*Continues*)

Table I. Continued

Reference	Study design; duration; setting; target	Population: sample size (*N*); Age M ± SD (range); % male	Intervention description; contact with intervention	Data time points; Comp; CG	How was vege intake measured?	Intake pre-intervention	Intake post-intervention	Intake at Follow-up	Change in vege consumption
Wolfenden *et al.* 2014	RCT; 1 months; phone + materials delivered to homes; Parents & children	394 parents from 30 pre-schools 4.3 ± 0.6 years (3–5 years) I:49.0%, C:54.3%	Weekly phone intervention + printed resources relating to healthy eating at home (based on Australian guide to healthy eating – AGHE). Aims: increase FV availability, supportive family routines & parental role modelling & self monitoring & develop contingencies for difficult situations. Contact: 4x30min phone contact + print materials	TP: Baseline, 12 month, 18 month Comp: 87% completed all 4 phone calls, & interviewers covered 97% of key intervention content CG: print material on AGHE only	Survey (CDQ): variety & *f* on previous *d*; *f*/ during previous week; FV combined; servings usually consumed.	serves not measured	V serves: I: 2.95 +/ − 0.12 C: 2.47 +/− 0.11	V serves: I: 2.98 +/− 0.11 C: 2.55 +/ − 0.10	I: sig higher at post-I & FU, $P < 0.01$
Wright *et al.* 2012	RCT; program: 6 weeks, school/ community activities: 4 months; ASP; children & teachers & parents	251 (I:121, C:130) I: 9.0 ± 1.6 years, C:8.3 ± 1.1 year, (–12 years) I:42%, C:38%	Two components: (1) 'Kids Nutrition & Fitness' (KNF): afterschool family lifestyle program & parental group encouraging healthy lifestyle behaviours, food pyramid, cooking patterns, (2) school & community environmental activities to create/deliver school based policy for physical & dietary change, professional development for teachers, home activities via bimonthly newsletters. Contact: KNF: 6 × 90 min sessions School/ Community activities: unclear duration	TP: Baseline, post-I, 12 months Comp: not stated CG: received general education (standard PA program offered by the school)	Survey (6 item): *f*/day	I: 1.51 +/− 0.5 C: 1.55 +/ − 0.69	—	—	I: +1.51(−2.11,5.50) C: +0.4 (−1.11,1.9), $P = 0.03$

I = intervention group; CG = control group; TP = timepoint; Comp = compliance – if no information provided in manuscript; V/vege = vegetable; F = fruit; PA = physical activity; *f* = frequency; NS = not significant; SSB = sugar sweetened beverages; Adj = adjusted; EO = exposure only; and ASP = after school program. Calculated by ((post intervention intake − baseline intake)/baseline intake × 100) or ((post intervention intake of intervention group − post intervention intake of control group)/post intervention intake of control × 100). This is only calculated for intake date, not for frequency data.

Table 2. Summary of intervention, effectiveness, intensity and quality of the studies included in this review ($n = 22$ studies)

Author	Target behaviour	Effectiveness*		Intensity		Study quality
		Short	Longer	Score	Rating	
(Annesi *et al.* 2009)	Lifestyle	Yes	—	12	Medium	Strong
(Bayer *et al.* 2009)	Lifestyle	Yes	Yes	16	High	Weak
(Castro *et al.* 2013)	Diet	Yes	Yes	12	Medium	Weak
(Corsini *et al.* 2011)	Vege	Yes	—	12	Medium	Weak
(Davis *et al.* 2011)	Diet	No	—	10	Low	Moderate
(De Bock *et al.* 2011)	Diet	Yes	Yes	12	Medium	Weak
(Engels *et al.* 2005)	Lifestyle	Yes	—	11	Medium	Weak
(Freedman & Nickell 2010)	Diet	Yes	—	11	Medium	Weak
(Gholami *et al.* 2015)	Vege	No	—	4	Low	Weak
(Haire-Joshu *et al.* 2008)	FV	No	No	11	Medium	Moderate
(Horne *et al.* 2011)	FV	Yes	Yes	11	Medium	Weak
(Horton *et al.* 2013)	Vege	No	—	12	Medium	Weak
(Latif *et al.* 2011)	FV	No	No	9	Low	Moderate
(Martinez-Andrade *et al.* 2014)	Lifestyle	No	No	12	Medium	Moderate
(Namenek Brouwer & Benjamin Neelon 2013)	FV	No	—	11	Medium	Weak
(Schwinn *et al.* 2014)	Diet	No	—	6	Low	Weak
(Slusser *et al.* 2013)	Lifestyle	No	No	12	Medium	Moderate
(Somerville *et al.* 2012)	FV	Yes	—	12	Medium	Weak
(Tabak *et al.* 2012)	Vege	No	—	12	Medium	Weak
(Witt & Dunn 2012)	Lifestyle	Yes	—	12	Medium	Moderate
(Wolfenden *et al.* 2014)	FV	Yes	Yes	10	Low	Moderate
(Wright *et al.* 2012)	Diet	Yes	Yes	13	High	Weak

*Short-term effectiveness = significant increase in vegetable consumption at 3 months; longer term effectiveness = significant increase in vegetable consumption at 6 months or more. Pre-school included pre-school and childcare centres. Aftersch = After-school; Comm = Community; Vege = vegetables, FV = fruit and vegetables.

The other two techniques that were associated with effective behaviour change were (1) the use of exposure to vegetables, although only associated with short-term change (6/9 studies) and (2) the provision of staff training, which was associated with both short-term (6/9 studies) and long term behaviour change (3/4 studies). However, both these techniques were only used in nine of the 22 interventions (41%, Table 5).

Change in vegetable intake

Based on the calculated percentage change in vegetable intake (calculated from the results reported in Table 1) interventions reported a mean increase in vegetable intake of 29% (range: −20% to +87%).

Discussion

The present review identified 22 studies that delivered home or community-based interventions aimed at increasing children's vegetable intake, either in isolation or in combination with other healthy eating and lifestyle messages. Just over half of studies reported a significant increase in children's vegetable intake at 3 months, with six out of ten studies that included a measure at 6 months are also effective. We estimate that the interventions were associated with an increase in vegetable intake of approximately 30% (range −20% to +87%). Based on Australian children's current vegetable intake, this equates to approximately a quarter to half of one vegetable serving. While this increase is small, incremental dietary improvements across the life stages are important and assist in establishing healthy eating patterns that may carry through into later childhood and beyond. Any increase in children's vegetable intake, regardless of the size, is important given the progressive declines usually observed during childhood (Australian Bureau of Statistics 2014).

Internationally, dietary guidelines (U.S. Department of Agriculture and U.S. Department of Health and

Table 3. Summary of intervention target, setting, duration, intensity and quality by short (3 months) and longer term (6 months) effectiveness ($n = 22$ studies)

	Short-term		Longer term	
	Effective ($n = 12$)	Ineffective ($n = 10$)	Effective ($n = 6$)	Ineffective ($n = 4$)
Target				
Vegetables	1	3	0	0
Fruit and vegetables	3	3	2	2
Healthy diet	4	2	3	0
Healthy lifestyle	4	2	1	2
Setting				
Home	2	5	1	1
Pre-school/childcare	4	2	3	0
After-school program	3	1	1	1
Community	3	2	1	2
Length of intervention				
0 to 4 weeks (0–1 month)	3	2	1	0
5 to 12 weeks (1–3 months)	4	3	1	2
13 to 24 weeks (3–6 months)	3	3	2	0
25 weeks or more (>6 months)	2	2	2	2
Intensity Rating				
Low (%)	1	4	1	1
Medium (%)	9	6	3	3
High (%)	2	0	2	0
Quality rating				
Weak (%)	9	5	5	0
Moderate (%)	2	5	1	4
Strong (%)	1	0	0	0

Table 4. Summary of intervention Intensity by short and longer term effectiveness ($n = 22$ studies)

	Short-term		Longer term	
	Effective (Mean)	Ineffective (Mean)	Effective (Mean)	Ineffective (Mean)
Intensity Score*				
Duration of intervention	2.75	2.8	3.3	3
Contact with intervention	3.75	2.7	3.7	3
Level of contact	3.5	3.2	3.3	3.5
Reach (no. of settings)	2	1.2	2	1.5
Overall score ($max = 20$,range 4–18)	*12*	*9.9*	*12.3*	*11*

*Maximum score for each component = 5.

Human Services 2010; National Health and Medical Research Council 2013) and public health campaigns (Capacci & Mazzocchi 2011; Council 2013) often promote fruits and vegetables together. Our results show that promoting fruits and vegetables together has limited benefit for vegetable intake, confirming previous findings (Evans *et al.* 2012), while targeting children's vegetable intake in isolation was least likely to increase usual vegetable intake. Our findings suggest that future initiatives should focus on whole meals within the context of a balanced diet and a healthy lifestyle, rather than target vegetables in isolation. Indeed vegetables tend to be consumed as part of a main meal rather than eaten alone. This finding challenges the notion of delivering simple nutrition education messages and is different to a previous review of dairy foods where single target

Table 5. Use of behaviour change techniques by short and longer term effectiveness

Behaviour change techniques	Short-term		Longer term		Total $n = 22$ (% of all studies)
	Effective ($N = 12$)	Ineffective ($N = 10$)	Effective ($N = 6$)	Ineffective ($N = 16$)	
1. Provide information on consequences of behaviour in general	**8**	**8**	**5**	**3**	**16 (72.7)**
2. Provide information on consequences of behaviour to the individual	4	5	3	2	9 (40.9)
3. Provide information about others' approval	0	1	0	1	1 (4.5)
4. Provide normative information about others' behaviour	0	0	0	0	0 (0)
5. Goal setting (behaviour)	4	5	2	3	9 (40.9)
6. Goal setting (outcome)	1	1	0	0	2 (9.1)
7. Action planning	0	2	0	1	2 (9.1)
8. Barrier identification/problem solving	2	5	1	2	7 (31.8)
9. Set graded tasks	1	1	0	1	2 (9.1)
10. Prompt review of behavioural goals	2	4	1	1	6 (27.3)
11. Prompt review of outcome goals	0	0	0	0	0 (0)
12. Prompt rewards contingent on effort or progress towards behaviour	0	2	0	2	2 (9.1)
13. Provide rewards contingent on successful behaviour	3	2	1	2	5 (22.7)
14. Shaping	0	0	0	0	0 (0)
15. Prompting generalisation of a target behaviour	1	0	0	0	1 (4.5)
16. Prompt self-monitoring of behaviour	3	4	1	3	7 (31.8)
17. Prompt self-monitoring of behavioural outcome	1	1	0	1	2 (9.1)
18. Prompting focus on past success	0	0	0	0	0 (0)
19. Provide feedback on performance	1	2	1	1	3 (13.6)
20. Provide information on where and when to perform the behaviour	2	1	1	0	3 (13.6)
21. Provide instruction on how to perform the behaviour	**4**	**8**	**2**	**3**	**12 (54.5)**
22. Model/Demonstrate the behaviour	**8**	**6**	**3**	**3**	**14 (63.6)**
23. Teach to use prompts/cues	1	1	1	1	2 (9.1)
24. Environmental restructuring	1	1	1	1	2 (9.1)
25. Agree behavioural contract	0	0	0	0	0 (0)
26. Prompt practice	**7**	**6**	**2**	**3**	**13 (59.1)**
27. Use of follow-up prompts	0	1	0	0	1 (4.5)
28. Facilitate social comparison	1	0	0	0	1 (4.5)
29. Plan social support/social change**/	***8***	***3***	***6***	***1***	***11 (50)***
30. Prompt identification as role model/position advocate	3	4	3	3	7 (31.8)
31. Prompt anticipated regret	0	0	0	0	0 (0)
32. Fear arousal	0	0	0	0	0 (0)
33. Prompt self-talk	1	0	0	0	1 (4.5)
34. Prompt use of imagery	1	0	0	0	1 (4.5)
35. Relapse prevention/coping planning	0	0	0	0	0 (0)
36. Stress management/emotional control training	0	2	0	0	2 (9.1)
37. Motivational interviewing	0	3	0	1	3 (13.6)
38. Time management	0	0	0	0	0 (0)
39. General communication skills training	2	5	1	3	7 (31.8)
40. Stimulate anticipation of future rewards	0	0	0	0	0 (0)
41. Exposure*	***6***	***3***	***2***	***2***	***9 (40.9)***
42. Provision of resources	**10**	**8**	**6**	**4**	**18 (81.8)**
43. Staff training*	***6***	***3***	***3***	***1***	***9 (40.9)***
44. Community/participant engagement	3	3	0	2	6 (27.3)
45. Economic incentives	1	1	1	0	2 (9.1)
46. Availability/accessibility	1	1	1	0	2 (9.1)

Bold: Commonly used techniques (used by greater than 50%) ***Bold/italics:*** Techniques associated with effective intervention; *short-term effectiveness, **longer term effectiveness.

messages were more effective in changing behaviour than targeting multiple food groups (Hendrie *et al.* 2012).

Effective interventions tended to be delivered in the pre-school/childcare centre setting, and this setting was particularly effective longer term where all three interventions reported significant increases in children's vegetable intake at 6 months. These findings are supported by the literature that suggests childcare settings are key in influencing children's dietary intakes by promoting positive mealtime environments, role-modelling positive eating practices, involving children in the meal time and allowing them choice to decide what and how much to eat (Golley *et al.* 2012; Bell *et al.* 2015). Additionally, childcare also engages parents about nutrition and assists in transferring positive nutrition practices into the home setting and by reaching out to parents and influencing the nutrition and food environment at home (Golley *et al.* 2012). It is also possible that such interventions coincided with, or prompted, a change in childcare nutrition policies or food service practices. In contrast, school environments have many competing curriculum priorities, which may dilute the intervention messages. Similarly, schools may have fewer resources (e.g. staff and access to training) to successfully deliver the intervention as intended, again potentially weakening the intervention effects. On the other hand childcare settings may have greater resources (e.g. higher staff to student ratios), some flexibility in their curriculum to implement intervention programs and a stronger parental expectation for the presence and implementation of nutrition policy.

A recent meta-analysis of school-based interventions in children aged 5–12 years (Evans *et al.* 2012) found that intervening in this setting resulted in an average increase in vegetable consumption of +0.07 servings. In comparison, our findings showed that targeting younger (2–12 years) children and intervening outside of the school setting was slightly more effective resulting in an average increase of a quarter to a half serve of vegetables (or ~30% increase in intake). In absolute terms, although a quarter to half a serve may seem small, any increase in vegetable intake at an early age is significant given the downward trajectory of vegetable intakes as young children progress through later childhood and into adolescence. The importance of intervention at an early age is well supported in the literature. For example, Caton *et al.* found age to be a significant predictor of eating patterns and acceptance, with younger children eating and enjoying novel vegetables more than older children (Caton *et al.* 2014). Furthermore, Birch & Ventura suggest that intervening before a child reaches school should be a priority and prevention efforts should explore all early childhood contexts such as family homes and childcare settings (Birch & Ventura 2009). Early years are considered the most effective and are characterised by 'high plasticity' and 'rapid transitions' and are a period of time when parents and caregivers have a high degree of control over their children's food environment and experiences (Anzman *et al.* 2010). As such, younger children are generally considered easier to influence than older children who have more established food preferences and greater independence in their food choices (Anzman *et al.* 2010).

However, despite the importance of interventions beginning at an early age, our results and the findings of others (Evans *et al.* 2012) highlight the difficulty of designing interventions to change children's vegetable intakes effectively. This is particularly demonstrated in our findings where huge disparities between interventions in effect were found, with reports of up to +87% change in vegetable intake and as low as −20%. Indeed, it has been shown that the taste of vegetables is not innately accepted by some children who are 'hard-wired' to reject pure vegetable flavours despite intensive conditioning attempts (Zeinstra *et al.* 2009). Many vegetables are bitter, have unfamiliar textures and provide little dietary energy (Hetherington *et al.* 2015); hence, overcoming such strong aversive innate preferences is difficult and may not be effective for all children (Caton *et al.* 2013). As such, children often require repeated exposure (Zajonc 1968; Caton *et al.* 2013) and positive reinforcement longer term in order to learn to like such foods (Cooke *et al.* 2011). In particular, persistence with repeated vegetable exposure in early childhood, prior to starting school, is likely to be important in the formation of taste preferences (Mikkila *et al.* 2005; Nicklaus & Remy, 2013). Indeed as our results indicate, exposure to vegetables is linked to short-term behaviour change and is supported by an emerging body of evidence using repeated exposure (and conditioning) of target vegetable stimuli, soups

or purees (Hausner *et al.* 2012; Caton *et al.* 2013; de Wild *et al.* 2013; Remy *et al.* 2013; Ahern *et al.* 2014; Bouhlal *et al.* 2014). However, while such studies have shown promising results in increasing intake, liking and acceptance of the test vegetable dishes, there is currently no evidence that responses to test stimuli generalise beyond that particular stimulus to habitual vegetable intake (Corsini *et al.* 2011). However, in the context of this review, acknowledging our search strategy was directed towards 'usual intake' rather than intakes of a specific targeted vegetable or test stimuli, designing interventions that combine exposure and conditioning methodologies with intervention strategies that influence 'usual' vegetable intake needs to be addressed by future research.

Greater frequency of participant contact with the intervention was also associated with effective behaviour change. While this review did not specifically consider the economic cost of interventions, it is an important practical consideration. The emergence of digital technologies may allow future initiatives to maintain regular, tailored contact with participants, while minimising cost relative to more traditional forms of face-to face contact (Cushing & Steele 2010).

Provision of knowledge is necessary for any intervention to be successful, but it is not sufficient to achieve behaviour change when used alone (Klein *et al.* 2015). This review found that provision of education resources, modelling or demonstrating behaviour and providing instruction were associated with better outcomes when combined with action based techniques such as planning for social support, increased exposure and provision of staff training. Further, planning for social support implies cooperation between parents and caregivers, and across settings such as the home and childcare facilities, to promote a consistent message. Indeed, targeting multiple settings was another important characteristic of effective interventions, suggesting that the full potential of initiatives can be optimised when multiple levels of the environment cooperate synergistically.

The present review synthesised relevant literature and identified key intervention attributes, which can inform the development of future initiatives aiming to increase young children's vegetable intake, primarily in the home and community settings. Because of the vast amount of literature and nature of systematic literature reviews, the scope of this paper needed to be contained, but still make a unique contribution to the area. We included a range of intervention types and outcome measures; however, excluded initiatives in the school setting, which were the focus of a recent review (Evans *et al.* 2012). However, school-based initiatives should not be excluded from future efforts to promote good nutrition and improve vegetable intake in children. We also excluded studies that did not report vegetable intake separately to fruit intake as it has been reported that improvements in fruit and vegetables intake, when reported together, is largely due to a change in fruit and not vegetable intake (Evans *et al.* 2012). Fruits and vegetables are consumed in different contexts, such as 'where' it is consumed, 'with whom' it is consumed and at what 'time' of day it is consumed (Mak *et al.* 2012) and as such, strategies to increase vegetable consumption are likely to differ from those for fruit.

Previous reviews have focused on 'how much' we can increase vegetable consumption (Knai *et al.* 2006; Evans *et al.* 2012). In contrast, we were particularly interested in 'how to' increase intake. We have critiqued a range of intervention components including the behaviour change techniques used, which has provided some insight to this question. However this critique was limited by the details provided in the published methodology. Details of the intervention messages and exactly how these were delivered were often brief. Therefore, there may have been other strategies that contributed to the success of the intervention that were not described, or instances where we may have not interpreted the description as intended.

The measurement of dietary intake is another commonly reported limitation (Livingstone & Robson 2000; Thompson *et al.* 2010), particularly in large scale community interventions. We allowed a range of outcome measurements to be included in this review; however, the common use of self-reported intake poses issues. It is associated with higher variability, meaning that small changes are more difficult to detect. Given our current definition of effectiveness, we may have biased our findings towards studies that were able to measure intake in a more robust way – such as in childcare settings where intake was often supervised, weighed and then the amount consumed reported in grams. Similarly, the heterogeneity in the measurement

of intake across the studies prevented us performing meta-analyses. However, we did attempt to summarise the findings by calculating the average change in vegetable intake as a percentage increase/decrease in the units reported, regardless of the significance levels, and found on average studies reported a 30% increase in children's vegetable intake.

As our findings show, despite the large body of literature describing interventions that target children's dietary intake, there is a need for more high quality, randomised and controlled interventions which target children's vegetable intake with longer term follow-up. Of the studies included in this review, only one was rated as strong quality, and only half included a measure of intake at 6 months or more. We have made recommendations about characteristics associated with effective intervention based on the authors' description and analysis of results, which varies between studies. Others advocate the need for effective techniques to be described using a systematic reporting process (e.g. adaptations of CONSORT reporting) to improve the quality of how studies are described (Cushing & Steele 2010). We also suggest the interventions themselves can be better described including details of the behaviour change techniques adopted using the CALO-RE taxonomy (Michie *et al*. 2011). Such description could compensate for the limitations of post-intervention surveys or qualitative techniques (Thomas *et al*. 2004b) that seek to elicit the opinions of parents (not always possible), children (often lacking the cognitive skills to articulate) and other caregivers (who were present during the intervention) on effective techniques and intervention components that contributed most to successful behaviour change. A higher level of robust detail in reporting the methods would allow public health behavioural interventions to be truly reproducible (Cushing & Steele 2010).

Conclusions

Interventions that target children's vegetable intake in the home or community settings are generally effective and may potentially increase intake by ~30%. Based on children's current intakes, which are well below recommendations, this equates to an average of a quarter to a half of a serve. Our review highlights the need for more high-quality RCT-based interventions targeting children's vegetable intake, with longer term follow-up to address the current low levels of consumption effectively and to bring them closer to recommended levels of intake. The findings in the current review identify key strategies and intervention characteristics that may optimise the effectiveness of future programs aiming to increase children's vegetable intake. However, a key challenge still remains in getting these strategies adopted and implemented at a broader community level to reach more children, as increasing children's intake in line with vegetable recommendations remains a significant challenge.

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Conflicts of interest

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This review did not require ethics approval. The authors declare no competing interest.

Contributions

All authors were involved in at least two of the following three processes: development of the selection criteria, data extraction process and writing of results. All authors contributed to the drafting and revisions of the manuscript and approved the final manuscript for publication.

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Supplementary File 1. Comprehensive data extraction data for review articles (.xls)

Supplementary File 2. PRISMA checklist.